VERIFICATION OF TRANSLATION

I, **Hiroyuki Takano** of **721, Marunouchi-Nakadori bldg., 2-3, Marunouchi 2-chome, Chiyoda-ku, Tokyo, 100-0005 JAPAN,** am the translator of **Japanese Patent Application No. 2003-200673** and I state that the following is a true translation to the best of my knowledge and belief.

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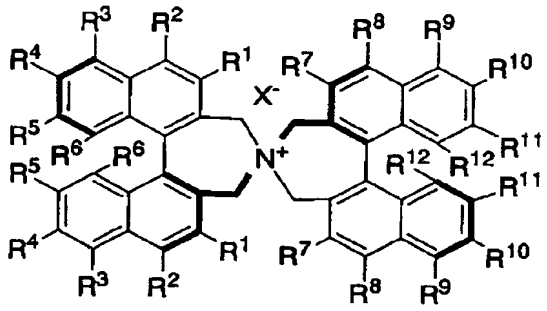
[TITLE OF DOCUMENT] DESCRIPTION

[TITLE OF THE INVENTION] OPTICALLY ACTIVE QUATERNARY AMMONIUM SALT, PRODUCTION METHOD THEREOF, AND METHOD FOR PRODUCING OPTICALLY ACTIVE α-AMINO ACID DERIVATIVE USING THE QUATERNARY AMMONIUM SALT

[CLAIMS]

[Claim 1] An optically active quaternary ammonium salt, represented by the following general formula (1):

[Chemical Formula 1]

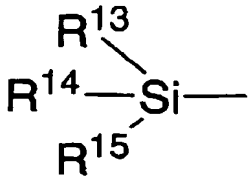


(1)

[wherein R^1, R^2, R^3, R^4, R^5, R^6, R^7, R^8, R^9, R^{10}, R^{11}, and R^{12} are each independently a hydrogen atom, a methyl group, an ethyl group, a straight, branched or cyclic alkyl group having 3 to 18 carbon atoms, a straight, branched or cyclic heteroalkyl group having 3 to 18 carbon atoms, a straight, branched or cyclic alkenyl group having 3 to 18 carbon atoms, a straight, branched or cyclic alkynyl group having 3 to 18 carbon atoms, an alkoxyl group having 1 to 18 carbon atoms, an aryl group having 5 to 20 carbon atoms, an aralkyl group having 5 to 35 carbon atoms, or a heteroaralkyl group having 5 to 35 carbon atoms;

with the proviso that at least one of R^1, R^2, R^3, R^4, R^5, R^6, R^7, R^8, R^9, R^{10}, R^{11}, and R^{12} is a substituent represented by the following general formula (2):

[Chemical Formula 2]



(2)

(wherein R^{13}, R^{14}, and R^{15} are each independently a methyl group, an ethyl group, a vinyl group, a straight, branched or cyclic alkyl group having 3 to 18 carbon atoms, a straight, branched or cyclic alkenyl group having 3 to 18 carbon atoms, a straight, branched or cyclic alkynyl group having 3 to 18 carbon atoms, an alkoxyl group having 1 to 18 carbon atoms, an aryl group having 5 to 20 carbon atoms, an aralkyl group having 5 to 25 carbon atoms, or a heteroaralkyl group having 5 to 25 carbon atoms.);

X^- is a fluorine ion, a chloride ion, a bromide ion, an iodide ion, a p-toluenesulfonic acid ion, a hydroxide ion, a thiocyanate ion, a hydrogen sulfate ion, a perchloric acid ion, or a hexafluorophosphoric acid ion; and the two binaphthyl moieties each have a chiral axis so that the absolute configurations of the two binaphthyl moieties are (R, R) or (S, S)].

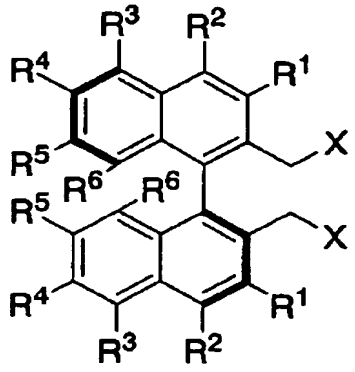
[Claim 2] A chemical compound according to claim 1, wherein R^1 and R^7, R^3 and R^9, R^4 and R^{10}, R^5 and R^{11}, and R^6 and R^{12} in the above general formula (1) are in each case identical to one another; and R^2 and R^8 are identical to one another and are each represented by the general formula (2); and X^- is a fluorine ion, a chloride ion, a bromide ion, an iodide ion, a p-toluenesulfonic acid ion, or a hydroxide ion.

[Claim 3] The chemical compound according to claim 1, wherein R^1, R^3, R^5, R^6, R^7, R^9, R^{11}, and R^{12} in the general formula above (1) are each independently a hydrogen atom; and R^2, R^4, R^8, and R^{10} are identical to one another and are each represented by the general formula (2); and X^- is a chloride ion, a bromide ion, an iodide ion, or a p-toluenesulfonic acid ion.

[Claim 4] The chemical compound according to claim 2, wherein in the above general formula (2), R^{13}, R^{14} and R^{15} are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group, and X^- is a bromide ion.

[Claim 5] An optically active binaphthyl compound represented by the following general formula (3):

[Chemical Formula 3]



(3)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each independently a hydrogen atom, a methyl group, an ethyl group, a straight, branched or cyclic alkyl group that has 3 to 18 carbon atoms, a straight, branched or cyclic heteroalkyl group that has 3 to 18 carbon atoms, a straight, branched or cyclic alkenyl group that has 3 to 18 carbon atoms, a straight, branched or cyclic alkynyl group that has 3 to 18 carbon atoms, an alkoxyl group that has 1 to 18 carbon atoms, an aryl group that has 5 to 20 carbon atoms, an aralkyl group that has 5 to 35 carbon atoms, or a heteroaralkyl group that has 5 to 35 carbon atoms;

with the proviso that at least one of R^1, R^2, R^3, R^4, R^5 and R^6 is a substituent represented by the above general formula (2):

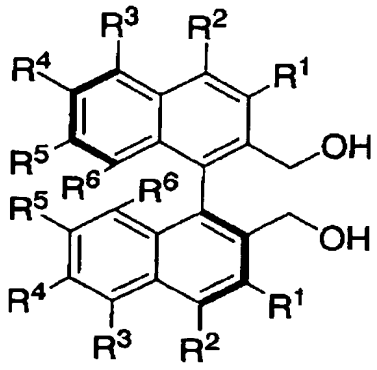
[Claim 6] The chemical compound according to claim 5, wherein R^1, R^3, R^5, and R^6 in the above general formula (3) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the general formula (2).

[Claim 7] The chemical compound according to claim 6, wherein in the above general formula (2), R^{13}, R^{14}, and R^{15} are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, a phenyl group, and X is a bromine atom.

[Claim 8] A method for producing the chemical compound according to any of claims 1 to 4 represented by the general formula (1) in which X^- is a chloride ion, a bromide ion, a iodide ion, or a p-toluenesulfonic acid ion, characterized in that the chemical compound according to any of claims 5 to 7 represented by the general formula (3) is reacted with ammonia.

[Claim 9] An optically active binaphthyl dihydroxyl compound represented by the following general formula (4):

[Chemical Formula 4]



(4)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each as defined in the

claim 5 represented by the general formula (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)].

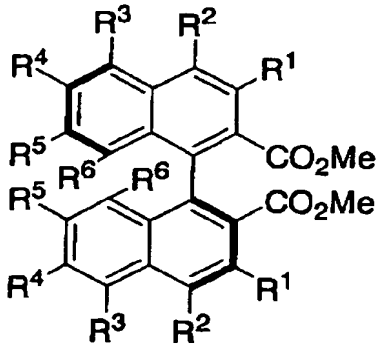
[Claim 10] The chemical compound according to claim 9, wherein R^1, R^3, R^5, and R^6 in the above general formula (4) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the above general formula (2).

[Claim 11] The chemical compound according to claim 10, wherein in the above general formula (2), R^{13}, R^{14}, and R^{15} are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

[Claim 12] A method for producing the chemical compound of the above general formula (3) according to any of claims 5 to 7, characterized in that the chemical compound of the above general formula (4) according to any of claims 9 to 11 is reacted with a halogen source or p-toluenesulfonyl chloride.

[Claim 13] An optically active binaphthyl diester compound represented by the following general formula (5):

[Chemical Formula 5]



(5)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each as defined in the claim 5 represented by the general formula (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)].

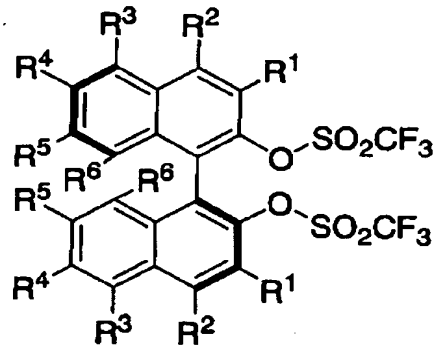
[Claim 14] The chemical compound according to claim 13, wherein R^1, R^3, R^5, and R^6 in the general formula above (5) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the above general formula (2).

[Claim 15] The chemical compound according to claim 14, wherein in the above general formula (2), R^{13}, R^{14}, and R^{15} are substituent independently and respectively selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, a phenyl group.

[Claim 16] A method for producing the compound according to any of claims 9 to 11 represented by the general formula (4), characterized in that the chemical compound according to

any of claims 13 to 15 represented by the general formula (5) is reacted with hydrogen anion.

[Claim 17] An optically active binaphthyl compound represented by the following general formula (6):



(6)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 in the general formula (6)are each as defined in the claim 5 represented by the general formula (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)].

[Claim 18] The chemical compound according to claim 17, wherein R^1, R^3, R^5, and R^6 in the general formula above (6) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the above general formula (2).

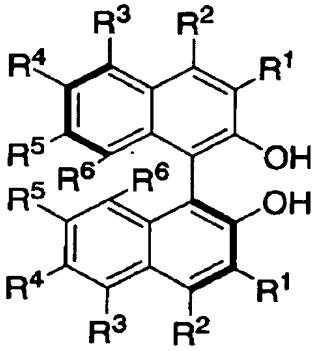
[Claim 19] The chemical compound according to claim 18, wherein in the above general formula (2), R^{13}, R^{14}, and R^{15} are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group,

a sec-butyl group, a tert-butyl group, an n-octyl group and a phenyl group.

[Claim 20] A method for producing the chemical compound of the general formula (5) according to any of claims 13 to 15, characterized in that the chemical compound of the general formula (6) according to any of claims 17 to 19 is reacted with carbon monoxide and methanol in the presence of a palladium catalyst and an organic base.

[Claim 21] An optically active binaphthol compound represented by the following general formula (7):

[Chemical Formula 7]



(7)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each as defined in claim 5 represented by the general formula (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)].

[Claim 22] The chemical compound according to claim 21, wherein R^1, R^3, R^5, and R^6 in the above general formula (7) are each independently a hydrogen atom; and R^2 and R^4 are identical

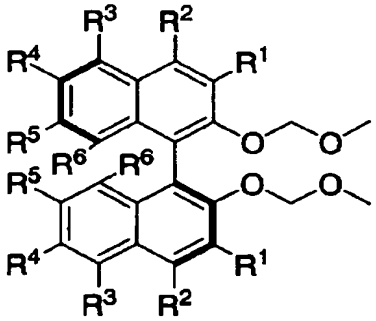
to one another and are each represented by the above general formula (2).

[Claim 23] The chemical compound according to claim 22, wherein in the above general formula (2), R^{13}, R^{14}, and R^{15} are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, a phenyl group.

[Claim 24] A method for producing the chemical compound according to any of claim 17 to 19 represented by the formula (6), characterized in that the chemical compound according to any of claims 21 to 23 represented by the formula (7) is reacted with a triflating agent.

[Claim 25] An optically active binaphthyl bis-methoxymethyl ether compound represented by the following general formula (8):

[Chemical Formula 8]



(8)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each as defined in the

claim 5 represented by the general formula (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)].

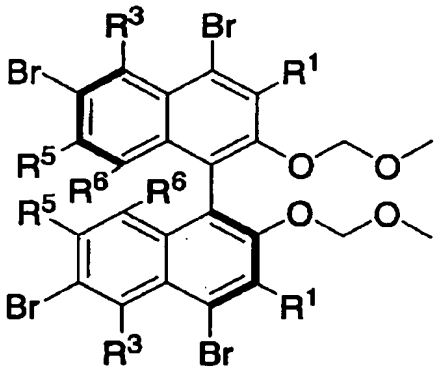
[Claim 26] The chemical compound according to claim 25, wherein R^1, R^3, R^5, and R^6 in the above general formula (8) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the above general formula (2).

[Claim 27] The chemical compound according to claim 26, wherein in the above general formula (2), R^{13}, R^{14}, and R^{15} are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, a phenyl group.

[Claim 28] A method for producing the chemical compound according to any of claims 21 to 23 represented by the general formula (7), characterized in that the chemical compound according to any of claims 25 to 27 represented by the general formula (8) is reacted with an acid.

[Claim 29] An optically active binaphthyl bis-methoxymethyl ether compound represented by the following general formula (9):

[Chemical Formula 9]



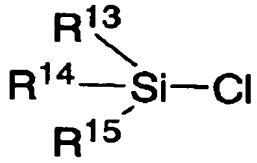
(9)

[wherein R^1, R^3, R^5, and R^6 are each as defined in the claim 5 represented by the general formula (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)].

[Claim 30] The chemical compound according to claim 29, wherein R^1, R^3, R^5, and R^6 in the above general formula (9) are each independently hydrogen.

[Claim 31] A method for producing the chemical compound according to any of claims 29 to 30 represented by the general formula (9), comprising reacting with an alkyl lithium represented by the following general formula (10):

[Chemical Formula 10]



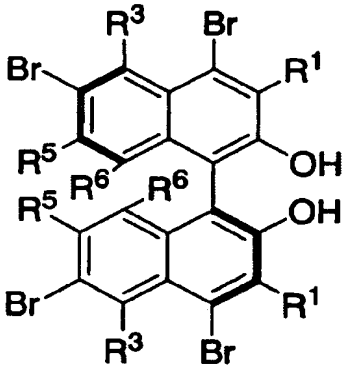
(10)

[wherein R^{13}, R^{14}, and R^{15} are each as defined in the above general formula (2)].

And a method for producing the chemical component according to any of claims 25 to 27 represented by the general formula (9) is subsequently reacting with the reaction product represented by the general formula (10).

[Claim 32] An optically active binaphthol compound represented by the following general formula (11):

[Chemical Formula 11]



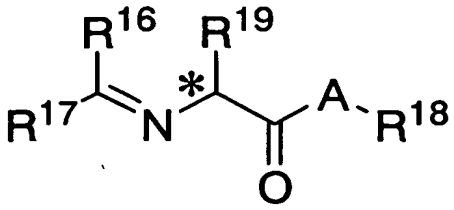
(11)

[wherein R^1, R^3, R^5, and R^6 are each as defined in the claim 5 represented by the general formula (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)].

A method for producing the chemical component according to any of claim 29 or 30 represented by the formula (9), comprising forming a binaphthoxide from an optically active binaphthol compound in the presence of an acid-capturing agent or by treatment with a base, and subsequently reacting the binaphthoxide with chloromethyl ether.

[Claim 33] A method for stereoselectively producing a compound represented by the following formula (14):

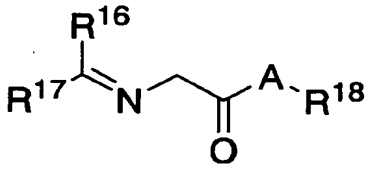
[Chemical Formula 14]



(14)

[wherein R^{16}, R^{17}, R^{18}, R^{19}, and A are as defined above, and the chiral carbon indicated by an asterisk '*' has an absolute configuration of (R) or (S)], comprising reacting, in a two-phase solution, a Schiff base of a glycine ester or an amide represented by the following formula (12):

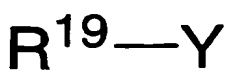
[Chemical Formula 12]



(12)

[wherein R^{16} and R^{17} are each independently a hydrogen atom or an aryl group that has 5 to 10 carbon atoms and may or may not be substituted with halogen, with the proviso that R^{16} and R^{17} are not a hydrogen atom at the same time; R^{18} is a straight, branched or cyclic alkyl group having 1 to 6 carbon atoms; and A is an oxygen atom or a nitrogen atom having a single hydrogen atom bound thereto] with an alkyl halide represented by the following formula (13):

[Chemical Formula 13]



(13)

[wherein R^{19} is a straight, branched or cyclic alkyl group having 1 to 10 carbon atoms, a straight, branched or cyclic alkenyl group having 3 to 10 carbon atoms, a straight, branched or cyclic alkynyl group having 3 to 10 carbon atoms, or an aralkyl group that has 5 to 25 carbon atoms and may or may not have its nucleus substituted with 1 to 15 halogen atoms; and Y is a chlorine atom, a bromine atom, or an iodine atom] in the presence of an optically active quaternary ammonium salt according to [1] to [8] above represented by the formula (1a) or (1b) and an inorganic base.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD TO WHICH THE INVENTION PERTAINS]

The present invention relates to a novel axially chiral, optically active spiro-quaternary ammonium salt and a production method thereof, as well as to an intermediate for use in the production of such an ammonium salt and a production method thereof. The present invention further relates to a method for stereoselectively producing an optically active α-amino acid derivative, a useful intermediate for the synthesis of pharmaceutical or agrochemical products, by using the ammonium salt as a phase transfer catalyst.

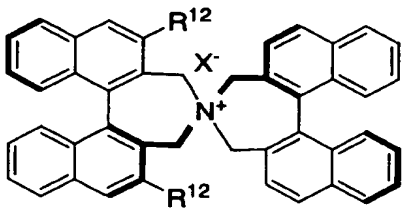
[0002]

[BACKGROUND ART]

As far as the background of the present invention is concerned, optically active spiro-quaternary ammonium salts (A) through (N), which are collectively represented by the following formula (15), are known:

[0003]

[Chemical Formula 15]



(15)

where

R^{12} = a hydrogen atom and X^- = a bromide ion (Compound (A));

R^{12} = a phenyl group and X^- = a bromide ion (Compound (B));

R^{12} = a β-naphthyl group and X^- = a bromide ion (Compound (C));

R^{12} = a 3,4,5-trifluorophenyl group and X^- = a bromide ion (Compound (D));

R^{12} = a 3,5-bistrifluoromethylphenyl group and X^- = a bromide ion (Compound (E));

R^{12} = a 3,5-bis(3,5-bistrifluoromethylphenyl)phenyl group and X^- = a bromide ion (Compound (F);

R^{12} = a 3,5-bis-*tert*-butylphenyl and X^- = a bromide ion (Compound (G));

R^{12} = a 3,5-bis(3,5-bis-tert-butylphenyl)phenyl group and X^- = a bromide ion (Compound (H));

R^{12} = a β-naphthyl group and X^- = a thiocyanic acid ion

(Compound (I));

R^{12} = a β-naphthyl group and X^- = a hydrogen sulfate ion (Compound (J));

R^{12} = a 3,5-bistrifluoromethylphenyl group and X^- = a thiocyanic acid ion (Compound (K));

R^{12} = a 3,5-bistrifluoromethylphenyl group and X^- = a hydrogen sulfate ion (Compound (L));

R^{12} = a 3,4,5-trifluorophenyl group and X^- = a thiocyanic acid ion (Compound (M)); and

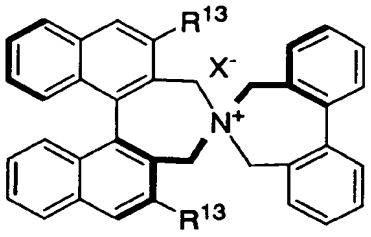
R^{12} = a 3,4,5-trifluorophenyl group and X^- = a hydrogen sulfate ion (Compound (N)) (See, for example, Patent Article No. 1 for Compounds (A) through (D), Non-Patent Article No. 1 for Compounds (E) and (F), Non-Patent Article No. 2 for Compounds (G) and (H), and Patent Article No. 2 for Compounds (I) through (N)).

[0004]

Also, optically active spiro-quaternary ammonium salts (O) and (P), which are collectively represented by the following formula (16), are known:

[0005]

[Chemical Formula 16]



(16)

where

R^{13} = a hydrogen atom and X^- = a bromide ion (Compound (O));

and

R^{13} = a β-naphthyl group and X^- = a bromide ion (Compound (P))

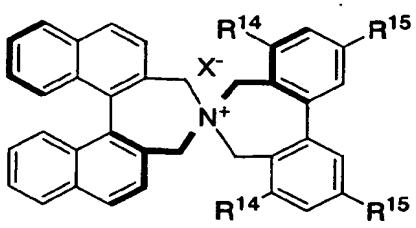
(See Patent Article No. 3).

[0006]

Furthermore, optically active spiro-quaternary ammonium salts (Q), (R), and (S), which are collectively represented by the following formula (17), are known:

[0007]

[Chemical Formula 17]



(17)

where

R^{14} = a β-naphthyl group, R^{15} = a hydrogen atom, and X^- = a bromide ion (Compound(Q);

R^{14} = a 3,5-diphenylphenyl, R^{15} = a hydrogen atom, and X^- = a bromide ion (Compound (R)); and

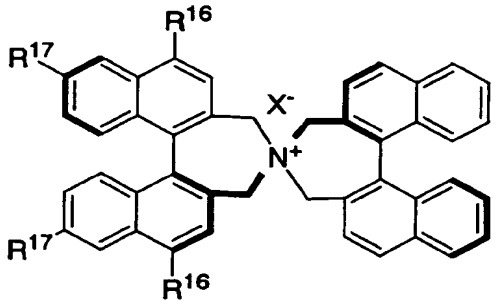
R^{14} = a 3,5-diphenylphenyl group, R^{15} = a phenyl group, and X^- = a bromide ion (Compound (S)) (See Patent Article No. 3).

[0008]

Still further, optically active spiro-quaternary ammonium salts (T), (U), and (V), which are collectively represented by the following formula (18), are known:

[0009]

[Chemical Formula 18]



(18)

where

R^{16} = R^{17} = a phenyl group and X^- = a bromide ion (Compound (T));

R^{16} = a phenyl group, R^{17} = a hydrogen atom, and X^- = a bromide ion (Compound (U)); and

R^{16} = R^{17} = a 3,5-diphenylphenyl group and X^- = a bromide ion (Compound (V)) (See Non-Patent Article No. 3).

[0010]

Some of Compounds (A) through (V), for example Compound (D), are highly reactive and stereoselective. Nonetheless, the asymmetric structure of these compounds results in as many as

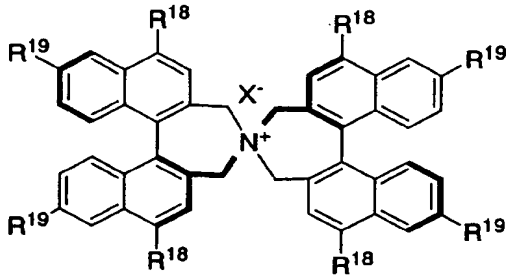
13 to 16 different steps involved in the synthesis of the catalysts when commercially available optically active 1,1-bi-2-naphthol is used as the starting material.

[0011]

Still further, optically active spiro-quaternary ammonium salts (W), (X), (Y), and (Z), which are collectively represented by the following formula (19), are known:

[0012]

[Chemical Formula 19]



(19)

where

R^{18} = R^{19} = a phenyl group and X^- = a bromide ion (Compound (W));

R^{18} = a phenyl group, R^{19} = a hydrogen atom, and X^- = a bromide ion (Compound (X));

R^{18} = R^{19} = a 3,5-diphenylphenyl group and X^- = a bromide ion (Compound (Y)); and

R^{18} = a 3,5-diphenylphenyl group, R^{19} = a hydrogen atom, and X^- = a bromide ion (Compound (Z)) (See, for example, Non-Patent Article No. 4). Since the two binaphtyl structures in these compounds are identical to each other, the number of the steps

involved in the synthesis of these catalysts is decreased to 8 to 11 steps. In terms of catalytic performance, these catalysts show, high reactivity and high selectivity of 90% or above toward certain substrates when used in the asymmetric alkylation of glycine derivatives as described in the non-patent article. However, the catalysts have been proved to show decreased reactively and selectivity toward some substrates such as ethyl iodide.

[0013]

Of all the compounds represented by the general formula (1) only those in which the substituents on the aromatic rings are either hydrogen or carbon atoms are known. In addition, no compounds are known that are represented by the formula (1) with silicon atoms or silicon-containing compounds directly bound to the aromatic rings.

[0014]

[Patent Article No. 1]

Japanese Patent Laid-Open Publication No. 2001-48866

[Patent Article No. 2]

Japanese Patent Laid-Open Publication No. 2002-173492

[Patent Article No. 3]

Japanese Patent Laid-Open Publication No. 2002-326992

[Non-Patent Article No. 1]

Keiji. Maruoka et. al., Angew. Chem. Int. Ed. 2002, 41, 4542-4544

[Non-Patent Article No. 2]

Keiji. Maruoka et. al. Angew. Chem. Int. Ed. 2003, 42, 579-582

[Non-Patent Article No. 3]

Keiji. Maruoka et. al., Tetrahedron Lett. 2003, 44, 3313-3316

[Non-Patent Article No. 4]

Keiji. Maruoka et. al. Tetrahedron: Asymm. 2003, 14(12), 1599-1602

[DISCLOSURE OF THE INVENTION]

[0015]

[PROBLEMS TO BE SOLVED BY THE INVENTION]

In view of the above-described state of the background art, objects of the present invention are:

1) to provide a novel axially chiral, optically active spiro-quaternary ammonium salt, that when used as a phase-transfer catalyst in the asymmetric alkylation of a glycine derivative, gives a high stereoselectivity of 90% ee or above and has a novel substituent to provide steric hindrance that allows the salt to be applied to a broader range of substrates with high selectivity;

2) in particular, to provide a compound in which each ring of the spiro-structure has the same structure and which is thus advantageous in terms of the number of steps involved in the synthesis of the catalyst for the said ammonium salts;

3) to provide a method for producing the ammonium salts;

4) to provide an intermediate for use in the production of the ammonium salts, and a method for producing the intermediate; and

5) to provide a method for using the ammonium salts as a phase transfer catalyst and thus stereoselectively producing an optically active α-amino acid derivative suitable for use as an intermediate in the synthesis of pharmaceutical or agrochemical products.

[0016]

[MEANS FOR SOLVING THE PROBLEMS]

In an effort to address the objects above, optically active ammonium salt that incorporates a novel alkyl- or aryl-substituted silyl group as a substituent on the binaphthyl aromatic ring has been founded and thus the present invention has been completed.

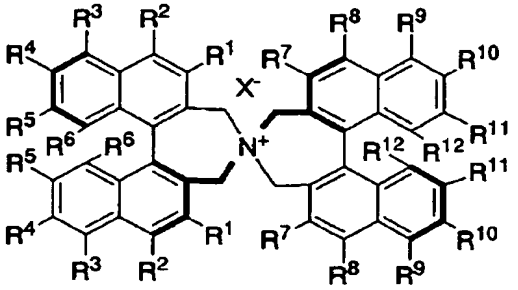
[0017]

Accordingly, the present invention concerns as follows.

1) An optically active quaternary ammonium salt, represented by the following general formula (1):

[0018]

[Chemical Formula 20]

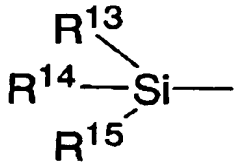


(1)

[wherein R^1, R^2, R^3, R^4, R^5, R^6, R^7, R^8, R^9, R^{10}, R^{11}, and R^{12} are each independently a hydrogen atom, a methyl group, an ethyl group, a straight, branched or cyclic alkyl group having 3 to 18 carbon atoms, a straight, branched or cyclic heteroalkyl group having 3 to 18 carbon atoms, a straight, branched or cyclic alkenyl group having 3 to 18 carbon atoms, a straight, branched or cyclic alkynyl group having 3 to 18 carbon atoms, an alkoxyl group having 1 to 18 carbon atoms, an aryl group having 5 to 20 carbon atoms, an aralkyl group having 5 to 35 carbon atoms, or a heteroaralkyl group having 5 to 35 carbon atoms; with the proviso that at least one of R^1, R^2, R^3, R^4, R^5, R^6, R^7, R^8, R^9, R^{10}, R^{11}, and R^{12} is a substituent represented by the following general formula (2):

[0019]

[Chemical Formula 21]



(2)

[wherein R^{13}, R^{14}, and R^{15} are each independently a methyl group, an ethyl group, a vinyl group, a straight, branched or cyclic

alkyl group having 3 to 18 carbon atoms, a straight, branched or cyclic alkenyl group having 3 to 18 carbon atoms, a straight, branched or cyclic alkynyl group having 3 to 18 carbon atoms, an alkoxyl group having 1 to 18 carbon atoms, an aryl group having 5 to 20 carbon atoms, an aralkyl group having 5 to 25 carbon atoms, or a heteroaralkyl group having 5 to 25 carbon atoms.];

X^- is a fluorine ion, a chloride ion, a bromide ion, an iodide ion, a p-toluenesulfonic acid ion, a hydroxide ion, a thiocyanate ion, a hydrogen sulfate ion, a perchloric acid ion, or a hexafluorophosphoric acid ion; and the two binaphthyl moieties each have a chiral axis so that the absolute configurations of the two binaphthyl moieties are (R, R) or (S, S)].

2) The chemical component wherein R^1 and R^7, R^3 and R^9, R^4 and R^{10}, R^5 and R^{11}, and R^6 and R^{12} in the general formula above (1) are in each case identical to one another; and R^2 and R^8 are identical to one another and are each represented by the general formula above (2); and X^- is a fluorine ion, a chloride ion, a bromide ion, an iodide ion, a p-toluenesulfonic acid ion, or a hydroxide ion.

3) The chemical component wherein R^1, R^3, R^5, R^6, R^7, R^9, R^{11}, and R^{12} in the above general formula (1) are each independently a hydrogen atom; R^2, R^4, R^8, and R^{10} are identical to one another and are each represented by the above general formula

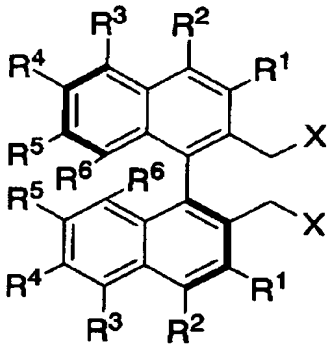
(2); and X^- is a chloride ion, a bromide ion, an iodide ion, or a p-toluenesulfonic acid ion.

4) The chemical compound according to 2), wherein R^{13}, R^{14} and R^{15} in the general formula above (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a *sec*-butyl group, a *tert*-butyl group, an n-octyl group, and a phenyl group, and and X^- is a bromide ion.

5) An optically active binaphthyl compound represented by the following general formula (3):

[0020]

[Chemical Formula 22]



(3)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each independently a hydrogen atom, a methyl group, an ethyl group, a straight, branched or cyclic alkyl group having 3 to 18 carbon atoms, a straight, branched or cyclic heteroalkyl group having 3 to 18 carbon atoms, a straight, branched or cyclic alkenyl group having 3 to 18 carbon atoms, a straight, branched or cyclic

alkynyl group having 3 to 18 carbon atoms, an alkoxyl group having 1 to 18 carbon atoms, an aryl group having 5 to 20 carbon atoms, an aralkyl group having 5 to 35 carbon atoms, or a heteroaralkyl group having 5 to 35 carbon atoms;

with the proviso that at least one of R^1, R^2, R^3, R^4, R^5, and R^6 is a substituent represented by the following general formula (2). X is a chlorine atom, a bromine atom, an iodine atom, or a p-toluenesulfonyloxy group; and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)].

6) The chemical compound according to 5) above, wherein R^1, R^3, R^5, and R^6 in the general formula above (3) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the above general formula above (2).

7) The chemical compound according to 6), wherein in the above general formula above (3), R^{13}, R^{14}, and R^{15} are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a *sec*-butyl group, a *tert*-butyl group, an n-octyl group, a phenyl group, and X is a bromine atom.

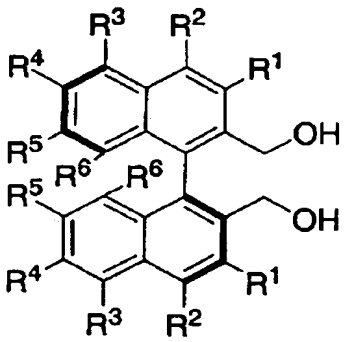
8) A method for producing the chemical compound according to any of 2) to 4) above represented by the above general formula above (1) in which X^- is a chloride ion, a bromide ion, an

iodide ion, or a p-toluenesulfonic acid ion, characterized in that the optically active binaphthyl compound according to any of 5) to 7) above represented by the above general formula (3) is reacted with ammonia.

9) An optically active binaphthyl dihydroxyl compound represented by the following general formula (4):

[0021]

[Chemical Formula 23]



(4)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each as defined in the 5) represented by the general formula above (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)]

10) The chemical compound according 9) above, wherein R^1, R^3, R^5, and R^6 in the above general formula (4) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the above general formula above (2).

11) The chemical compound according to 10), wherein R^{13}, R^{14}, and R^{15} in the above general formula above (2) are each independently a substituent selected from the group consisting

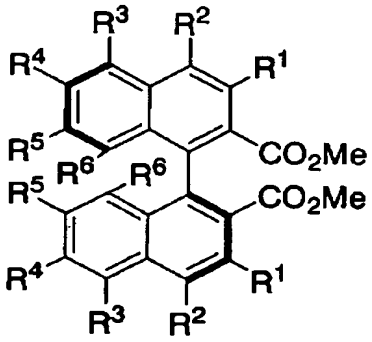
of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a *sec*-butyl group, a *tert*-butyl group, an n-octyl group, and a phenyl group.

12) A method for producing the chemical compound of the above general formula above (3)according to any of 5) to 7), characterized in that the optically active binaphthyl dihydroxyl compound of the general formula above (4) according to any of 9) to 11) is reacted with a halogen source or p-toluenesulfonyl chloride.

13) An chemical compound optically active binaphthyl diester compound represented by the following general formula (5):

[0022]

[Chemical Formula 24]



(5)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each as defined in the 5) represented by the general formula above (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)]

14) The chemical compound according to 13) above, wherein R^1,

R^3, R^5, and R^6 in the above general formula above (5) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the general formula (2).

[0023]

15) The chemical compound according to 14), wherein R^{13}, R^{14}, and R^{15} in the above general formula above (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a *sec*-butyl group, a *tert*-butyl group, an n-octyl group, and a

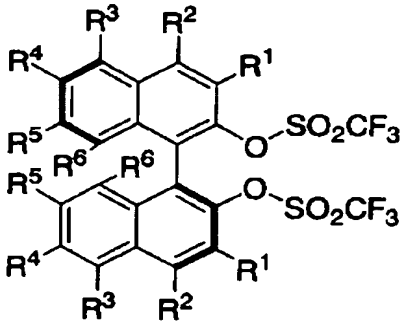
16) A method for producing the chemical compound according to any of 9) to 11) above represented by the above general formula (4), characterized in that the chemical compound according to any of 13) to 15) above represented by the above general formula above (5) is reacted with a hydrogen anion.

[0024]

17) An optically active binaphthyl compound represented by the following general formula (6):

[0025]

[Chemical Formula 25]



(6)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each as defined in the 5) represented by the above general formula (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)]

18) The chemical compound according to 17), wherein R^1, R^3, R^5, and R^6 in the above general formula above (6) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the above general formula above (2).

19) The chemical compound according to 18), wherein R^{13}, R^{14}, and R^{15} in the above general formula above (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

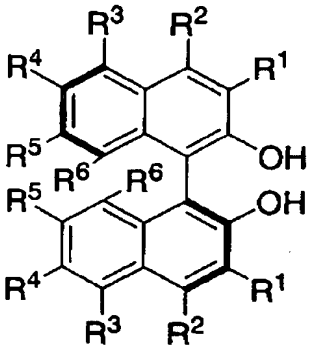
20) A method for producing the chemical compound of the above general formula (5) according to any of 13) to 15), characterized in that the chemical compound of the above

general formula (6) according to any of 17) to 19) is reacted with carbon monoxide and methanol in the presence of a palladium catalyst and an organic base.

21) An optically active binaphthol compound represented by the following general formula (7):

[0026]

[Chemical Formula 26]



(7)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each as defined in the 5) represented by the general formula above (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)]

22) The chemical compound according to 21), wherein R^1, R^3, R^5, and R^6 in the general formula above (7) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the above general formula above (2).

23) The chemical compound according to 22), wherein R^{13}, R^{14}, and R^{15} in the above general formula (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group,

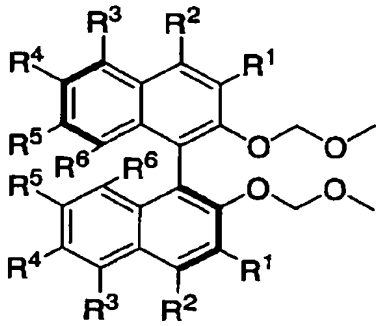
an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

24) A method for producing the chemical compound according to any of 17) to 19) represented by the general formula above (6), characterized in that the chemical compound according to any of 21) to 23) above represented by the above general formula (7) is reacted with a triflating agent.

25) An optically active binaphthyl bis-methoxymethyl ether compound represented by the following general formula (8):

[0027]

[Chemical Formula 27]



(8)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each as defined in the 5) represented by the general formula above (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)]

26) The chemical compound according to 25) above, wherein R^1, R^3, R^5, and R^6 in the above general formula (8) are each independently a hydrogen atom; and R^2 and R^4 are identical to one another and are each represented by the above general formula (2).

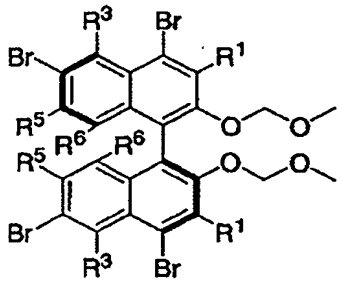
27) The chemical compound according to 26), wherein R^{13}, R^{14}, and R^{15} in the above general formula (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

28) A method for producing the chemical compound according to any of 21) to 23) above represented by the aboe general formula (7), characterized in that the chemical compound according to any of 25) to 27) above represented by the above general formula (8) is reacted with an acid.

29) An optically active binaphthyl bis-methoxymethyl ether compound represented by the following general formula (9):

[0028]

[Chemical Formula 28]



(9)

[wherein R^1, R^2, R^3, R^4, R^5, and R^6 are each as defined in the 5) represented by the general formula above (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)]

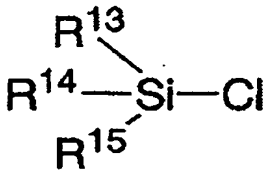
30) The chemical compound according to 29), wherein R^1, R^3, R^5,

and R^6 in the above general formula above (9) are each independently a hydrogen atom.

31) A method for producing the chemical compound according to any of 25) to 27) above represented by the above general formula (8), comprising reacting with an alkyl lithium the chemical compound according to any of 29) to 30) represented by the general formula above (9), and subsequently reacting with the reaction product a silyl chloride represented by the following general formula above (10):

[0029]

[Chemical Formula 29]



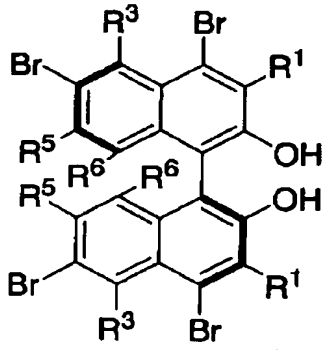
(10)

(wherein R^{13}, R^{14}, and R^{15} are each as defined in the general formula above (2))

32) An optically active binaphthol compound represented by the following general formula (11):

[0030]

[Chemical Formula 30]



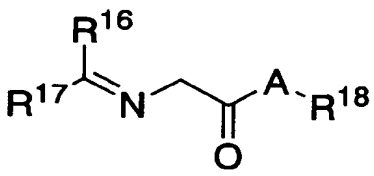
(11)

[wherein R^1, R^3, R^5, and R^6 are each as defined in the 5) represented by the general formula above (3), and the binaphthyl moiety has a chiral axis so that the absolute configuration of the binaphthyl moiety is (R) or (S)] A method for producing the chemical compound according to any of 29) or 30) above represented by the abeve general formula (9), comprising forming a binaphthoxide from an optically active binaphthol compound in the presence of an acid-capturing agent or by treatment with a base: and subsequently reacting the binaphthoxide with chloromethyl ether.

33) In the presence of the chemical compound according to 1) to 4) above represented by the general formula above (1) and an inorganic base, the following general formula (12):

[0031]

[Chemical Formula 31]



(12)

[wherein R^{16} and R^{17} are each independently a hydrogen atom or an aryl group that has 5 to 10 carbon atoms and may or may not be substituted with halogen, with the proviso that R^{16} and R^{17} are not a hydrogen atom at the same time; R^{18} is a straight, branched or cyclic alkyl group having 1 to 6 carbon atoms; and A is an oxygen atom or a nitrogen atom having a single hydrogen atom bound thereto] with an alkyl halide represented by the following general formula (13):

[0032]

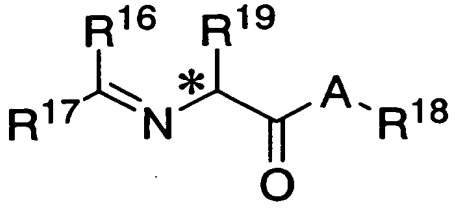
[Chemical Formula 32]

$$R^{19}—Y \qquad (13)$$

(wherein R^{19} is a straight, branched or cyclic alkyl group having 1 to 10 carbon atoms, a straight, branched or cyclic alkenyl group having 3 to 10 carbon atoms, a straight, branched or cyclic alkynyl group having 3 to 10 carbon atoms, or an aralkyl group that has 5 to 25 carbon atoms and may or may not have its nucleus substituted with 1 to 15 halogen atoms; and Y is a chlorine atom, a bromine atom, or an iodine atom); comprising reacting, in a two-phase solution, a Schiff base of a glycine ester or an amide, and the following general formula (14):

[0033]

[Chemical Formula 33]



(14)

(wherein R^{16}, R^{17}, R^{18}, R^{19}, and A are as defined above, and the chiral carbon indicated by an asterisk '*' has an absolute configuration of (R) or (S)), that is a method for stereoselectively producing a compound.

[0034]

The present invention will now be described in detail.

[0035]

While the optically active quaternary ammonium salt of the present invention shown by the above general formula above (1) may be any of the compounds defined above, it preferably is a compound in which R^1 and R^7, R^3 and R^9, R^4 and R^{10}, R^5 and R^{11}, and R^6 and R^{12} are in each case identical to one another, R^2 and R^8 are identical to one another and are each represented by the general formula (2), and X^- is a fluoride ion, a chloride ion, a bromide ion, an iodide ion, a p-toluenesulfonic acid ion, or a hydroxide ion. Of such compounds, particularly preferred are those in which R^1, R^3, R^5, R^6, R^7, R^9, R^{11}, and R^{12} are each a hydrogen atom, R^2, R^4, R^8, and R^{10} are identical to one another and are each represented by the general formula (2), and X^- is a chloride ion, a bromide ion, an iodide ion, or a p-toluenesulfonic acid ion. Of these,

the most preferred are those in which R^{13}, R^{14}, and R^{15} in the general formula above (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

[0036]

Examples of the compound shown by the above general formula (1) include, spiro-bis[{(R)-1,1'-bi-{4,6-bis(trimethylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide, spiro-bis[{(R)-1,1'-bi-{4,6-bis(triethylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide, spiro-bis[{(R)-1,1'-bi-{4,6-bis(tripropylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide, spiro-bis[{(R)-1,1'-bi-{4,6-bis(triisopropylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide, spiro-bis[{(R)-1,1'-bi-{4,6-bis(tributylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide, spiro-bis[{(R)-1,1'-bi-{4,6-bis(triphenylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide, spiro-bis[{(R)-1,1'-bi-{4,6-bis(dimethyloctylsilyl)naphthyl}}2,2'-dimethyl]ammonium bromide, spiro-bis[{(R)-1,1'-bi-{4,6-bis(*tert*-butyldimethylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide, spiro-bis[{(R)-1,1'-bi-{4,6-bis(dimethylphenylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide, spiro-bis[{(R)-1,1'-bi-{4,6-bis(*tert*-butyldiphenylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide,

spiro-bis[{(R)-1,1'-bi-{4,6-bis(trimethylsilyl)naphthyl}}-2,2'-dimethyl]ammonium iodide, spiro-bis[{(R)-1,1'-bi-{4,6-bis(trimethylsilyl)naphthyl}}-2,2'-dimethyl]ammonium chloride, spiro-bis[{(R)-1,1'-bi-{4,6-bis(trimethylsilyl)naphthyl}}-2,2'-dimethyl]ammonium fluoride and spiro-bis[{(R)-1,1'-bi-{4,6-bis(trimethylsilyl)naphthyl}}-2,2'-dimethyl]ammonium hydroxide, and the corresponding (S)-forms as enantiomers.

[0037]

While the optically active binaphthyl compound of the present invention shown by the above general formula above (3) may be any of the compounds defined above, it preferably is a compound in which R^1, R^3, R^5, and R^6 are each a hydrogen atom, and R^2 and R^4 are identical to one another and are each represented by the general formula (2). Of these, particularly preferred are those in which R^{13}, R^{14}, and R^{15} in the general formula above (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group. Of these compounds, those in which X is a chlorine atom, a bromine atom, an iodine atom, or p-toluenesulfonyloxy group are preferred, with ones in which X is a bromine atom being particularly the most preferred.

[0038]

Examples of the optically active binaphthyl compound of the present invention shown by the above general formula above (3) include, (R)-1,1'-bi-{2-bromomethyl-4,6-bis(trimethylsilyl)}naphthyl, (R)-1,1'-bi-{2-bromomethyl-4,6-bis(triethylsilyl))naphthyl, (R)-1,1'-bi-{2-bromomethyl-4,6-bis(tripropylsilyl)}naphthyl, (R)-1,1'-bi-{2-bromomethyl-4,6-bis(triisopropylsilyl)}naphthyl, (R)-1,1'-bi-{2-bromomethyl-4,6-bis(tributylsilyl)}naphthyl, (R)-1,1'-bi-{2-bromomethyl-4,6-bis(triphenylsilyl)}naphthyl, (R)-1,1'-bi-{2-bromomethyl-4,6-bis(dimethyloctylsilyl)}naphthyl, (R)-1,1'-bi-{2-bromomethyl-4,6-bis(*tert*-butyldimethylsilyl)}naphthyl, (R)-1,1'-bi-{2-bromomethyl-4,6-bis(dimethylphenylsilyl)}naphthyl, (R)-1,1'-bi-{2-bromomethyl-4,6-bis(*tert*-butyldiphenylsilyl)}naphthyl, (R)-1,1'-bi-{2-chloromethyl-4,6-bis(trimethylsilyl)}naphthyl, (R)-1,1'-bi-{2-chloromethyl-4,6-bis(trimethylsilyl)}naphthyl and (R)-1,1'-bi-{2-iodomethyl-4,6-bis(trimethylsilyl)}naphthyl, and the corresponding (S)-forms as enantiomers.

[0039]

The compound of the present invention according to claims 1 to 4 represented by the above general formula (1) can be obtained by reacting the optically active binaphthyl compound of the above general formula (3) with ammonia. The ammonia used may be a 10% to saturated aqueous ammonia and preferably a 20 to 28wt% aqueous ammonia. Water or an organic solvent

inert to the reaction may be added as a solvent. The reaction is preferably carried out in a sealed condition to avoid loss of ammonia. The amount of ammonia used is typically 1 to 8 equivalents, and preferably 2 to 5 equivalents, relative to the substrate used. The reaction is typically carried out at a temperature of 5°C to 30°C and at a substrate concentration of 5 to 20wt%, and is carried out over a time period of typically 5 to 72 hours, and preferably 10 to 36 hours. In this manner, the desired ammonium salt can be obtained in high yield.

[0040]

While the optically active binaphthyl dihydroxy compound of the present invention shown by the above general formula above (4) may be any of the compounds defined above, it preferably is a compound in which R^1, R^3, R^5, and R^6 are each a hydrogen atom, and R^2 and R^4 are identical to one another and are each represented by the general formula (2). Of these, the most preferred are those in which R^{13}, R^{14}, and R^{15} in the general formula above (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

[0041]

Examples of the optically active binaphthyl dihydroxy

compound of the present invention shown by the above general formula (4) include, specifically, (R)-1,1'-bi-{4,6-bis(trimethylsilyl)-2-hydroxymethyl}naphthyl, (R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-hydroxymethyl}naphthyl, (R)-1,1'-bi-{4,6-bis(tripropylsilyl)-2-hydroxymethyl}naphthyl, (R)-1,1'-bi-{4,6-bis(triisopropylsilyl-2-hydroxymethyl)naphthyl, (R)-1,1'-bi-{4,6-bis(tributylsilyl)-2-hydroxymethyl}naphthyl, (R)-1,1'-bi-{4,6-bis(triphenylsilyl)-2-hydroxymethyl}naphthyl, (R)-1,1'-bi-{4,6-bis(dimethyloctylsilyl)-2-hydroxymethyl}naphthyl, (R)-1,1'-bi-{4,6-bis(*tert*-butyldimethylsilyl)-2-hydroxymethyl)naphthyl, (R)-1,1'-bi-{4,6-bis(dimethylphenylsilyl)-2-hydroxymethyl}naphthyl and (R)-1,1'-bi-{4,6-bis(*tert*-butyldiphenylsilyl)-2-hydroxymethyl}naphthyl, and the corresponding (S)-forms as enantiomers.

[0042]

The optically active binaphthyl compound of the present invention represented by the above general formula (3) can be obtained as follows: For example, when it is desired to produce a halogenated product, the optically active binaphthyl dihydroxy compound of the above general formula above (4) is reacted with triphenylphosphine, and carbon tetrabromide or carbon tetrachloride in a proper solvent such as tetrahydrofuran. The reaction is carried out at a substrate concentration of typically 5 to 20wt% and at a temperature of

typically -10°C to 50°C, and preferably 10°C to 30°C, and is carried out over a time period of typically 10 minutes to 10 hours, and preferably 1 hour to 5 hours. In this manner, the desired dihalogenated product can be obtained in high yield. When it is desired to produce a sulfonyloxy product, the optically active binaphthyl dihydroxy compound represented by the above general formula (4) is reacted with p-toluenesulfonyl chloride in a proper solvent such as dichloromethane and in the presence of an acid-capturing agent such as triethylamine. The reaction is carried out at a substrate concentration of typically 5 to 20wt% and at a temperature of typically -40°C to 20°C, and preferably -10°C to 10°C, and is carried out over a time period of typically 10 minutes to 10 hours, and preferably 1 hour to 5 hours. In this manner, the desired sulfonyloxy product can be obtained in high yield.

[0043]

While the optically active binaphthyl diester compound of the present invention shown by the above general formula above (5) may be any of the compounds defined above, the most preferred is a compound in which R^1, R^3, R^5, and R^6 are each a hydrogen atom, and R^2 and R^4 are identical to one another and are each represented by the general formula (2). Of these, particularly preferred are those in which R^{13}, R^{14}, and R^{15} in the above general formula (2) are each independently a

substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

[0044]

Examples of the optically active binaphthyl diester compound of the present invention shown by the above general formula (5) include (R)-1,1'-bi-{4,6-bis(trimethylsilyl)-2-methoxycarbonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-methoxycarbonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(tripropylsilyl)-2-methoxycarbonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(triisopropylsilyl)-2-methoxycarbonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(tributylsilyl)-2-methoxycarbonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(triphenylsilyl)-2-methoxycarbonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(dimethyloctylsilyl)-2-methoxycarbonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(*tert*-butyldimethylsilyl)-2-methoxycarbonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(dimethylphenylsilyl)-2-methoxycarbonyl}naphthyl and (R)-1,1'-bi-{4,6-bis(*tert*-butyldiphenylsilyl)-2-methoxycarbonyl}naphthyl, and the corresponding (S)-forms as enantiomers.

[0045]

The optically active binaphthyl dihydroxy compound of the present invention represented by the above general formula (4)

can be obtained, for example, by reacting the optically active binaphthyl diester compound of the above general formula above (5) with a hydrogen anion such as $LiAlH_4$ in a proper solvent such as tetrahydrofuran. The reaction is carried out at a substrate concentration of typically 5 to 30wt% and at a temperature of typically -20°C to 30°C, and preferably -10°C to 10°C, and is carried out over a time period of typically 10 minutes to 5 hours, and preferably 20 minutes to 2 hours. In this manner, the desired dihydroxyl methyl product can be obtained in high yield.

[0046]

While the optically active binaphthyl compound of the present invention shown by the general formula above (6) may be any of the compounds defined above, it preferably is a compound in which R^1, R^3, R^5, and R^6 are each a hydrogen atom, and R^2 and R^4 are identical to one another and are each represented by the general formula (2). Of these, the most preferred are those in which R^{13}, R^{14}, and R^{15} in the above general formula (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

[0047]

Examples of the optically active binaphthyl compound of

the present invention shown by the above general formula (6) include, (R)-1,1'-bi-{4,6-bis(trimethylsilyl)-2-trifluoromethanesulfonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-trifluoromethanesulfonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(tripropylsilyl)-2-trifluoromethanesulfonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(triisopropylsilyl)-2-trifluoromethanesulfonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(tributylsilyl)-2-trifluoromethanesulfonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(triphenylsilyl)-2-trifluoromethanesulfonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(dimethyloctylsilyl)-2-trifluoromethanesulfonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(*tert*-butyldimethylsilyl)-2-trifluoromethanesulfonyl}naphthyl, (R)-1,1'-bi-{4,6-bis(dimethylphenylsilyl)-2-trifluoromethanesulfonyl}naphthyl and (R)-1,1'-bi-{4,6-bis(*tert*-butyldiphenylsilyl)-2-trifluoromethanesulfonyl}naphthyl, and the corresponding enantiomers, or (S)-forms.

[0048]

The optically active binaphthyl dimethyl ester compound of the present invention represented by the above general formula (5) can be obtained, for example, by reacting the optically active binaphthyl compound of the above general formula (6) with carbon monoxide and methanol in a proper solvent such as dimethyl sulfoxide in the presence of a

palladium catalyst and an organic base, such as diisopropylethylamine, for capturing an acid, in a carbon monoxide atmosphere, which may be pressurized. The reaction is carried out at a substrate concentration of typically 5 to 30wt% under a pressure of typically 1 to 30atm, and preferably 5 to 20atm, and at a temperature of typically room temperature to 200°C, and preferably 80°C to 130°C, and is typically carried out over a time period of 24 to 72 hours. The palladium catalyst may have no valency or it may be prepared in the reaction system from a divalent acetate or the like. The palladium catalyst is typically used in an amount of 5 to 20mol% relative to the substrate. The base is used in an amount of typically 2 to 8 equivalents, and preferably 2.5 to 5 equivalents, relative to the substrate. Methanol is used in an amount of 2 to 200 equivalents, and preferably 10 to 50 equivalents, relative to the substrate. In this manner, the desired diester product can be obtained in high yield.

[0049]

While the optically active binaphthol compound of the present invention shown by the above general formula above (7) may be any of the compounds defined above, it preferably is a compound in which R^1, R^3, R^5, and R^6 are each a hydrogen atom, and R^2 and R^4 are identical to one another and are each represented by the general formula (2). Of these, most preferred are those in which R^{13}, R^{14}, and R^{15} in the above

general formula (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

[0050]

Examples of the optically active binaphthol compound of the present invention shown by the above general formula above (7) include, specifically, (R)-1,1'-bi-{4,6-bis(trimethylsilyl)-2-hydroxy}naphthyl, (R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-hydroxy}naphthyl, (R)-1,1'-bi-{4,6-bis(tripropylsilyl)-2-hydroxy}naphthyl, (R)-1,1'-bi-{4,6-bis(triisopropylsilyl)-2-hydroxy}naphthyl, (R)-1,1'-bi-{4,6-bis(tributylsilyl)-2-hydroxy}naphthyl, (R)-1,1'-bi-{4,6-bis(triphenylsilyl)-2-hydroxy}naphthyl, (R)-1,1'-bi-{4,6-bis(dimethyloctylsilyl)-2-hydroxy}naphthyl, (R)-1,1'-bi-{4,6-bis(*tert*-butyldimethylsilyl)-2-hydroxy}naphthyl, (R)-1,1'-bi-{4,6-bis(dimethylphenylsilyl)-2-hydroxy}naphthyl and (R)-1,1'-bi-{4,6-bis(*tert*-butyldiphenylsilyl)-2-hydroxy}naphthyl, and the corresponding (S)-forms as enantiomers.

[0051]

The optically active binaphthyl compound of the present invention represented by the above general formula above (6) can be obtained, for example, by reacting the optically active binaphthol compound of the above general formula (7) with a

triflating agent, such as a trifluoromethanesulfonic acid anhydride or trifluoromethanesulfonyl chloride, in an inert solvent such as dichloromethane in the presence of an organic base such as triethylamine. The reaction is typically carried out at a substrate concentration of 5 to 30wt% and at a temperature of -78°C to room temperature, and is typically carried out over a time period of 30 minutes to 3 hours. In this manner, the desired ditriflate product can be obtained in high yield.

[0052]

While the optically active binaphthyl bis-methoxymethyl ether compound of the present invention shown by the above general formula (8) may be any of the compounds defined above, it preferably is a compound in which R^1, R^3, R^5, and R^6 are each a hydrogen atom, and R^2 and R^4 are identical to one another and are each represented by the general formula (2). Of these, most preferred are those in which R^{13}, R^{14}, and R^{15} in the general formula above (2) are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

[0053]

Examples of the optically active binaphthyl diether compound of the present invention shown by the above general

formula (8) include, specifically, (R)-1,1'-bi-{4,6-bis(trimethylsilyl)-2-methoxymethoxy}naphthyl, (R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-methoxymethoxy}naphthyl, (R)-1,1'-bi-{4,6-bis(tripropylsilyl)-2-methoxymethoxy}naphthyl, (R)-1,1'-bi-{4,6-bis(triisopropylsilyl)-2-methoxymethoxy}naphthyl, (R)-1,1'-bi-{4,6-bis(tributylsilyl)-2-methoxymethoxy}naphthyl, (R)-1,1'-bi-{4,6-bis(triphenylsilyl)-2-methoxymethoxy}naphthyl, (R)-1,1'-bi-{4,6-bis(dimethyloctylsilyl)-2-methoxymethoxy}naphthyl, (R)-1,1'-bi-{4,6-bis(*tert*-butyldimethylsilyl)-2-methoxymethoxy}naphthyl, (R)-1,1'-bi-{4,6-bis(dimethylphenylsilyl)-2-methoxymethoxy}naphthyl and (R)-1,1'-bi-{4,6-bis(*tert*-butyldiphenylsilyl)-2-methoxymethoxy}naphthyl, and the corresponding (S)-forms as enantiomers.

[0054]

The optically active binaphthol compound of the present invention represented by the general formula above (7) can be obtained, for example, by reacting the optically active binaphthyl bis-methoxymethyl ether compound of the above general formula (8) with an organic acid, such as p-toluenesulfonic acid, in a proper solvent, such as dichloromethane and methanol, or a mixed solvent. Preferably, the organic acid is used in an amount of 2 to 3 equivalents relative to the substrate. The reaction is carried out at a substrate concentration of typically 5 to 20wt% and at a

temperature of typically 10°C to 80°C, preferably 30°C to 60°C, and is carried out over a time period of typically 20 minutes to 48 hours, and preferably 2 hours to 24 hours. In this manner, the desired binaphthol product can be obtained in high yield.

[0055]

The optically active binaphthyl bis-methoxymethyl ether compound of the present invention represented by the above general formula (8) can be obtained, for example, as follows: The optically active binaphthyl dieter compound of the above formula (9) is reacted with butyl lithium in a proper solvent, such as tetrahydrofuran, to replace the bromine atoms with lithium atoms. The reaction product is then reacted with the silyl chloride of the formula (10a) above Using the alkyl lithium in an amount of typically 8 to 12 equivalents relative to the substrate, the reaction is carried out at a substrate concentration of typically 5 to 20wt% and at a temperature of typically -100°C to -50°C, and preferably -85°C to -75°C, and is carried out over a time period of typically 20 minutes to 3 hours, and preferably 30 minutes to 2 hours. In this manner, the desired lithio product can be obtained. To this product, the alkyl silyl chloride is added, at the same temperature, in an amount of 4 to 8 equivalents relative to the substrate, and the reaction is carried out at a temperature of typically -80°C to 30°C, and preferably 0°C to room temperature, over a

time period of typically 20 minutes to 2 hours, and preferably 30 minutes to 1 hour. In this manner, the desired product can be obtained in high yield.

[0056]

While the optically active binaphthyl bis-methoxymethyl ether compound of the present invention shown by the above general formula (9) may be any of the compounds defined above, it preferably is a compound in which R^1, R^3, R^5 and R^6 are each a hydrogen atom.

[0057]

While the silyl chloride of the present invention shown by the above general formula above (10) may be any of the compounds defined above, compounds are the most preferred in which R^{13}, R^{14}, and R^{15} are each independently a substituent selected from the group consisting of a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-octyl group, and a phenyl group.

[0058]

The compound of the present invention represented by the formula above (9) can be obtained, for example, by reacting the compound of the above formula (11) with sodium hydride in a solvent, such as tetrahydrofuran, to form an alkoxide, followed by addition of chloromethylmethyl ether. The reaction is carried out at a substrate concentration of typically 5 to

20wt% and at a temperature of typically -40°C to room temperature, and preferably -10°C to 0°C, and is carried out over a time period of typically 20 minutes to 3 hours, and preferably 30 minutes to 2 hours. In this manner, the desired product can be obtained in high yield. Of the compounds shown by the above formula (9), those in which R^1, R^3, R^5, and R^6 are each a hydrogen atom can be synthesized according to the process described in *J. Org. Chem.*, 2001, 66, 2358.

[0059]

According to the present invention, the optically active quaternary ammonium salt according to Claims 1 to 4 represented by the above general formula (1) is used as a chiral phase-transfer catalyst. In the stereoselective production of the compound of the above general formula (14), a Schiff base of a glycine ester shown by the above general formula (12) is asymmetrically alkylated with a halogenated alkyl of the above general formula (13) in a two-phase solvent system using the optically active quaternary ammonium salt of the above general formula (1) as a phase-transfer catalyst. The solvent used is a mixture of a water-immiscible hydrocarbon solvent, such as toluene, and a 40 to 60wt% aqueous solution of an alkaline metal, such as potassium hydroxide and cesium hydroxide, with the ratio of the organic phase to the aqueous phase being in the range of 5:1 to 1:3, preferably, 5:1 to 1:1. This reaction is carried out at a

substrate concentration of typically 5 to 20wt% and at a temperature of typically -40°C to 10°C, and preferably -25°C to 5°C, and is carried out over a time period of typically 1 hour to 200 hours, and preferably 5 hours to 180 hours. The amount of the phase-transfer catalyst used is in the range of 0.2 to 2mol%, and preferably in the range of 0.8 to 1.2mol% relative to the substrate. In this manner, the desired optically active α-amino acid derivative can be obtained in high yield in a highly stereoselective manner. In the above-describe process, the reaction product shown by the general above formula (16) is given as an (S)-form when the axially chiral, optically active quaternary ammonium salt of the above general formula (1) to serve as the phase-transfer catalys has an absolute configuration of (R, R). Conversely, the product is given as an (R)-form when the catalyst has an absolute configuration of (S, S).

[0060]

[Effect of the Invention]

The present invention of axially chiral, optically active spiro-quaternary ammonium salts is characterized by the followings:

1) to give a high stereoselectivity of 90% ee or above when used as a phase-transfer catalyst in the asymmetric alkylation of a glycine derivative

2) it can be applied to a broader range of substrates with

high selectivity

3) fewer steps are involved in the synthesis of the catalysts when used as a phase-transfer catalyst, the ammonium salts allow the stereoselective production of optically active α-amino acid derivatives, useful intermediates in the synthesis of pharmaceutical or agrochemical products. Because of these advantages, the present invention is of significant importance in industrial applications.

[0061]

[Example]

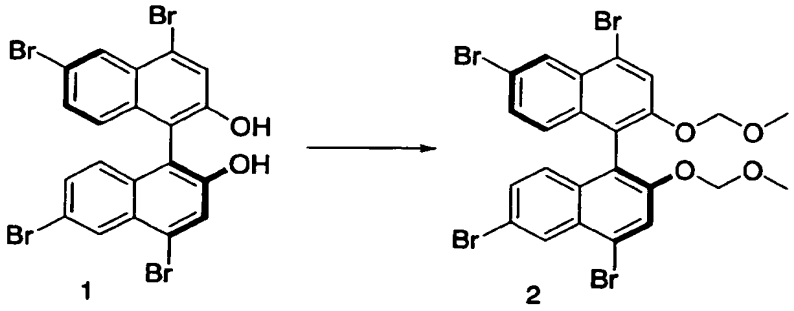
The present invention will now be described in further detail with reference to examples. These examples, however, are provided by way of example only and are not intended to limit the scope of the invention in any way.

[0062]

Example 1 Synthesis of (R)-1,1'-bi-(4,6-dibromo-2-methoxymethoxy)naphthyl (2)

[0063]

[Chemical Formula 34]



In an argon atmosphere, 60% sodium hydride (0.880 g, 22

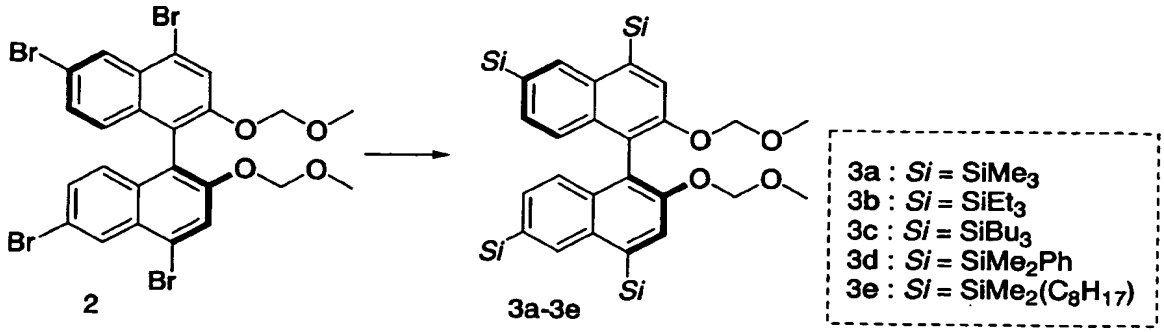
mmol) was added to a tetrahydrofuran solution (50 mL) of Compound 1 (6.02 g,10 mmol) at 0°C and the mixture was stirred for 10 minutes. Subsequently, chloromethyl ether (1.67 mL, 22 mmol) was added at 0°C, and the reaction mixture was allowed to warm to room temperature and was then stirred for 1 hour. After completion of the reaction, the reaction mixture was poured into water and was extracted with dichloromethane. The dichloromethane solution was dried over anhydrous sodium sulfate and was concentrated under reduced pressure. To the resulting white solid, hexane (30 mL) was added and the solution was filtered to give Compound 2 (6.90 g, 10 mmol) in a quantitative manner.

^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.43 (2H, d, J = 2.4 Hz, Ar-H), 7.94 (2H, s, Ar-H), 7.33 (2H, dd, J = 2.4 Hz, 9.2 Hz, Ar-H), 6.96 (2H, d, J = 9.2 Hz, Ar-H), 5.07 (2H, d, J = 7.2 Hz, Ar-OCH_2), 4.98 (2H, d, J = 7.2 Hz, Ar-OCH_2), 3.20 (6H, s, OCH_3).

Examples 2 through 6 Synthesis of (R)-1,1'-bi-{4,6-bis(trialkylsilyl)-2-methoxymethoxy}naphthyls (3a through 3e)

[0064]

[Chemical Formula 35]



In an argon atmosphere, a 1.40M *tert*-butyllithium solution (1.93 mL, 2.7 mmol) was added dropwise to a tetrahydrofuran solution (10 mL) of Compound 2 (0.207 g, 0.30 mmol) at -78°C, and the mixture was stirred for 15 minutes. Subsequently, a corresponding trialkylchlorosilane (1.80 mmol) was added at -78°C, and the reaction mixture was allowed to warm to room temperature and was then stirred for 4 hours. After completion of the reaction, the reaction mixture was poured into water and was extracted with dichloromethane. The dichloromethane solution was dried over anhydrous sodium sulfate and was concentrated under reduced pressure. The resulting residue was subjected to a silica gel column chromatography and eluted with a mixed solvent of diethylether/hexane to give Compounds 3a through 3e in yields of 60 to 85%.

[0065]

Chemical data for the products of Examples 2 through 6 are shown below.

<Product of Example 2 (Compound 3a)>

(R)-1,1'-bi-{4,6-bis(trimethylsilyl)-2-methoxymethoxy}naphthyl: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.29 (2H, s, Ar-H), 7.72 (2H, s, Ar-H), 7.31 (2H, dd, J = 1.2 Hz, 8.4 Hz, Ar-H), 7.16(2H, d, J = 8.4 Hz, Ar-H), 5.03 (2H, d, J = 6.4 Hz, Ar-OCH_2), 4.95 (2H, d, J = 6.4 Hz, Ar-OCH_2), 3.15 (6H, s, OCH_3), 0.55 (18H, s, $SiCH_3$), 0.27 (18 H, s, $SiCH_3$).

<Product of Example 3 (Compound 3b)>

(R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-methoxymethoxy}naphthyl: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.24 (2H, s, Ar-H), 7.67 (2H, s, Ar-H), 7.31 (2H, dd, J = 1.2 Hz, 8.4 Hz, Ar-H), 7.19 (2H, d, J = 8.4 Hz, Ar-H), 5.04 (2H, d, J = 6.4 Hz, Ar-OCH_2), 4.91 (2H, d, J = 6.4 Hz, Ar-OCH_2), 2.97 (6H, s, OCH_3), 1.40-0.80 (60H, m, $SiCH_2CH_3$).

<Product of Example 4 (Compound 3c)>

(R)-1,1'-bi-{4,6-bis(tributylsilyl)-2-methoxymethoxy}naphthyl: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.25 (2H, s, Ar-H), 7.64 (2H, s, Ar-H), 7.31 (2H, d, J = 8.4 Hz, Ar-H), 7.21 (2H, d, J = 8.4 Hz, Ar-H), 5.04 (2H, d, J = 6.4 Hz, Ar-OCH_2), 4.89 (2H, d, J = 6.4 Hz, Ar-OCH_2), 2.89 (6H, s, OCH_3), 1.39-0.80 (108H, m, $SiCH_2CH_2CH_2CH_3$).

<Product of Example 5 (Compound 3d)>

(R)-1,1'-bi-{4,6-bis(dimethylphenylsilyl)-2-methoxymethoxy}naphthyl: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.05 (2H, s, Ar-H), 7.33 (2H, s, Ar-H), 7.59-7.28 (22H, m, Ar-H), 7.10 (2H, d, J = 8.4 Hz, Ar-H), 5.97 (2H, d, J = 6.4 Hz, Ar-OCH_2), 4.88

(2H, d, J = 6.4 Hz, Ar-OCH_2), 3.04 (6H, s, OCH_3), 0.67 (12H, s, $SiCH_3$), 0.41 (12H, s, $SiCH_3$).

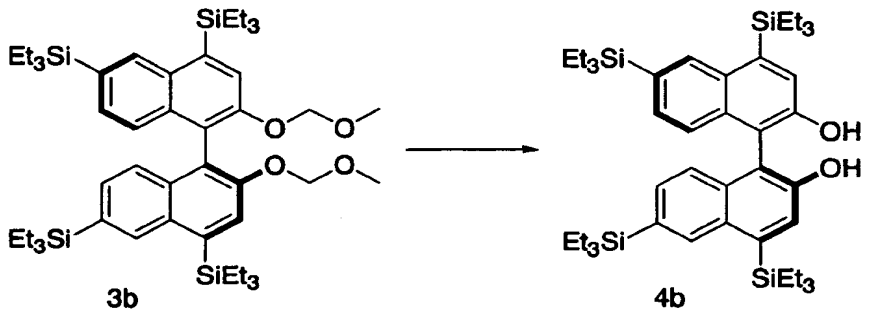
<Product of Example 6 (Compound 3e)>

(R)-1,1'-bi-{4,6-bis(dimethyloctylsilyl)-2-methoxymethoxy}naphthyl: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.27 (2H, s, Ar-H), 7.70 (2H, s, Ar-H), 7.30 (2H, dd, J = 1.2 Hz, 8.4 Hz, Ar-H), 7.16 (2H, d, J = 8.4 Hz, Ar-H), 5.03 (2H, d, J = 6.4 Hz, Ar-OCH_2), 4.93 (2H, d, J = 6.4 Hz, Ar-OCH_2), 3.09 (6H, s, OCH_3), 1.45-0.72 (68H, m, SiC_8H_{17}), 0.48 (12H, s, $SiCH_3$), 0.27 (12H, s, $SiCH_3$).

Example 7 Synthesis of (R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-hydroxy}naphthyl (4b)

[0066]

[Chemical Formula 36]



p-toluenesulfonic acid monohydrate (0.114g, 0.60 mmol) was added to Compound 3b (0.30 mmol) in dichloromethane (10 mL) and methanol (10 mL) at room temperature, and the mixture was stirred at 50°C for 24 hours. After completion of the reaction, the reaction mixture was poured into water and was

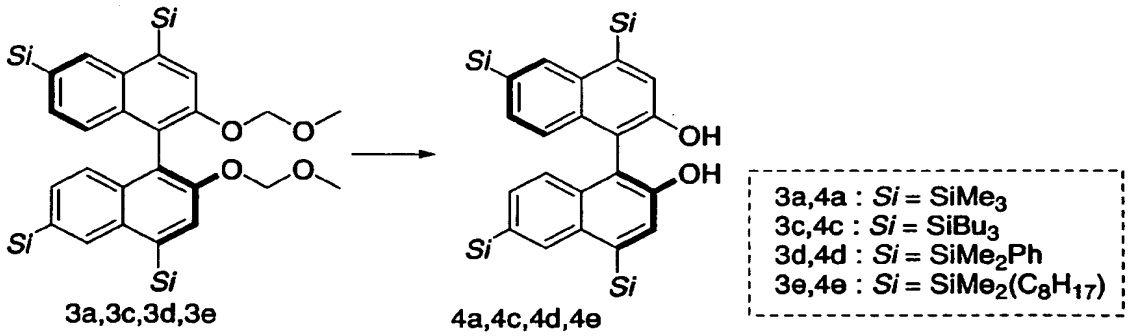
extracted with dichloromethane. The dichloromethane solution was dried over anhydrous sodium sulfate and was concentrated under reduced pressure to give Compound 4b in a quantitative yield.

^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.28 (2H, s, Ar-H), 7.54 (2H, s, Ar-H), 7.39 (2H, dd, J = 1.2 Hz, 8.4 Hz, Ar-H), 7.29 (2H, d, J = 8.4 Hz, Ar-H), 4.99 (2H, s, OH), 1.11-0.80 (60H, m, $SiCH_2CH_3$).

Examples 8 through 11 Synthesis of (R)-1,1'-bi-{4,6-bis(trialkylsilyl)-2-hydroxy}naphthyls (4a, 4c, 4d, and 4e)

[0067]

[Chemical Formula 37]



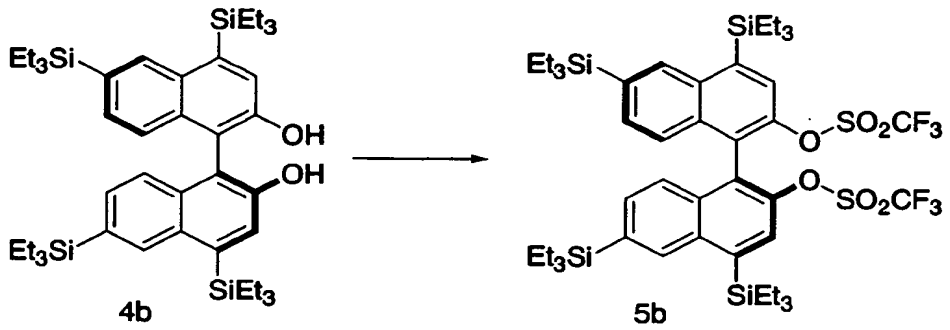
To obtain Compounds 4a, 4c, 4d, and 4e in quantitative yields, the same procedure was followed as in Example 7, except that Compound 3a, 3c, 3d, or 3e was used as the starting material in place of Compound 3b.

[0068]

Example 12 Synthesis of (R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-trifluoromethanesulfonyl}naphthyl (5b)

[0069]

[Chemical Formula 38]



In an argon atmosphere, triethylamine (11.1 mmol) was added to a dichloromethane solution (25 mL) of Compound 4b (3.70 mmol), and the mixture was cooled to -78°C. Trifluoromethanesulfonic acid anhydride (11.1 mmol) was added dropwise, and the mixture was allowed to warm to room temperature, followed by stirring for 1 hour. Subsequently, the reaction mixture was poured into a saturated aqueous solution of ammonium chloride and the solution was extracted with dichloromethane. The dichloromethane solution was dried over anhydrous sodium sulfate and was concentrated under reduced pressure. After concentration, the resulting residue was subjected to a silica gel column chromatography and eluted with a mixed solvent of diethylether/hexane to give Compound 5b in a quantitative yield.

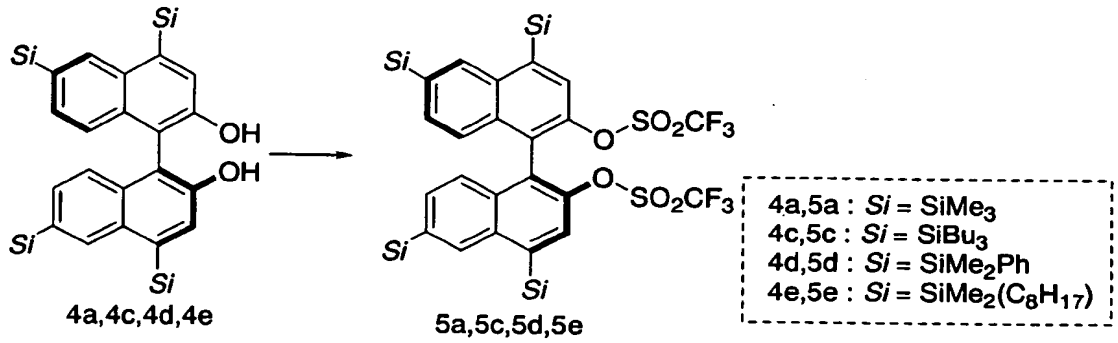
^{1}H-NMR (400MHz, $CDCl_3$) σ 8.35 (2H, s, Ar-H), 7.71 (2H, s, Ar-H), 7.47 (2H, dd, J = 1.2 Hz, 8.4 Hz, Ar-H), 7.30 (2H, d, J = 8.4 Hz, Ar-H), 1.11-0.85 (60H, m, $SiCH_2CH_3$).

Examples 13 through 16 Synthesis of (R)-1,1'-bi-{4,6-

bis(trialkylsilyl)-2-trifluoromethanesulfonyl}naphthyls (5a, 5c, 5d, and 5e)

[0070]

[Chemical Formula 39]



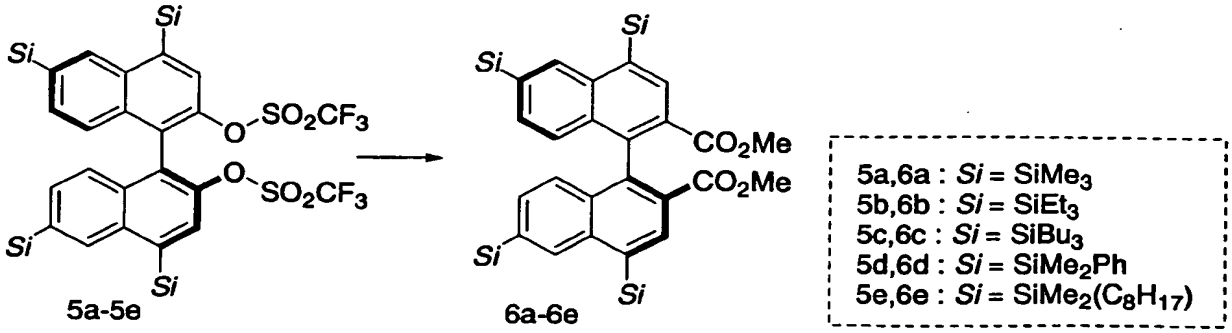
To obtain Compounds 5a, 5c, 5d, and 5e in quantitative yields, the same procedure was followed as in Example 12, except that Compound 4a, 4c, 4d, or 4e was used as the starting material in place of Compound 4b.

[0071]

Examples 17 through 21 Synthesis of (R)-1,1'-bi-{4,6-bis(trialkylsilyl)-2-methoxycarbonyl}naphthyls (6a through 6e)

[0072]

[Chemical Formula 40]



In an argon atmosphere, iPr_2NEt (0.51 mL), MeOH (1.0 mL) and DMSO (2.0 mL) were added to a mixture containing one of Compounds 5a through 5e (0.70 mmol), $Pd(OAc)_2$ (15 mol%), and dppp (16.5 mol%). While the reaction vessel was pressurized to 15 atm under CO atmosphere, the mixture was stirred at 100°C for 24 hours. Subsequently, the reaction mixture was poured into water and the solution was extracted with ethyl acetate. The extract was dried over anhydrous sodium sulfate and was concentrated under reduced pressure. After concentration, the resulting residue was subjected to a silica gel column chromatography and eluted with a mixed solvent of diethylether/hexane to give Compounds 6a through 6e in yields of 58 to 80%.

Chemical data for the products of Examples 17 through 21 are shown below.

<Product of Example 17 (Compound 6a)>

(R)-1,1'-bi-{4,6-bis(trimethylsilyl)-2-methoxycarbonyl}naphthyl: ^{1}H-NMR (400MHz, $CDCl_3$) σ 8.34 (2H, s, Ar-H), 8.33 (2H, s, Ar-H), 7.31 (2H, d, J = 8.4 Hz, Ar-H), 7.03 (2H, d, J = 8.4 Hz, Ar-H), 3.53 (6H, s, CO_2CH_3), 0.57 (18H, s, $SiCH_3$), 0.30 (18H, s, $SiCH_3$).

<Product of Example 18 (Compound 6b)>

(R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-methoxycarbonyl}naphthyl: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.31 (2H, s, Ar-H), 8.28 (2H, s, Ar-H), 7.32 (2H, dd, J = 1.2 Hz, 8.4 Hz,

Ar-H), 7.11 (2H, d, J = 8.4 Hz, Ar-H), 3.32 (6H, s, CO_2CH_3), 1.12-0.82 (60H, m, $SiCH_2CH_3$).

<Product of Example 19 (Compound 6c)>

(R)-1,1'-bi-{4,6-bis(tributylsilyl)-2-methoxycarbonyl}naphthyl: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.32 (2H, s, Ar-H), 8.27 (2H, s, Ar-H), 7.32 (2H, d, J = 8.4 Hz, Ar-H), 7.13 (2H, d, J = 8.4 Hz, Ar-H), 3.27 (6H, s, CO_2CH_3), 1.38-0.81 (108H, m, $SiCH_2CH_2CH_2CH_3$).

<Product of Example 20 (Compound 6d)>

(R)-1,1'-bi-{4,6-bis(dimethylphenylsilyl)-2-methoxycarbonyl}naphthyl: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.40 (2H, s, Ar-H), 8.11 (2H, s, Ar-H), 7.52 (2H, d, J = 8.4 Hz, Ar-H), 7.38-7.22 (20H, m, Ar-H), 7.10 (2H, d, J = 8.4 Hz, Ar-H), 3.49 (6H, s, CO_2CH_3), 0.70 (12H, s, $SiCH_3$), 0.37 (12H, s, $SiCH_3$).

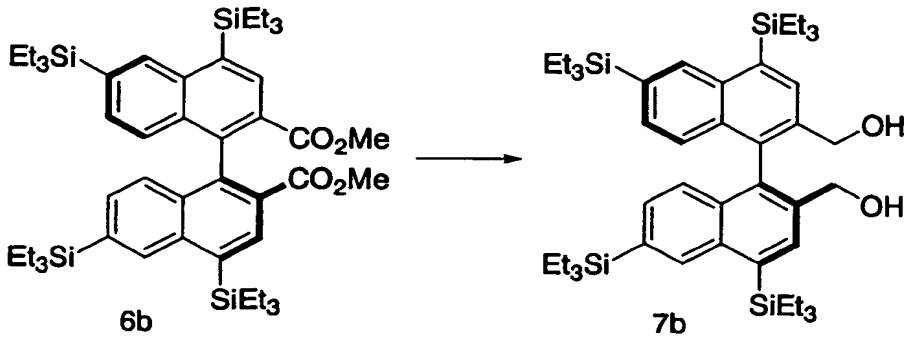
<Product of Example 21 (Compound 6e)>

(R)-1,1'-bi-{4,6-bis(dimethyloctylsilyl)-2-methoxycarbonyl}naphthyl: ^{1}H-NMR (400MHz, $CDCl_3$) σ 8.33 (2H, s, Ar-H), 8.30 (2H, s, Ar-H), 7.29 (2H, dd, J = 1.2 Hz, 8.4 Hz, Ar-H), 7.04 (2H, d, J = 8.4 Hz, Ar-H), 3.47 (6H, s, CO_2CH_3), 1.43-0.75 (68H, m, SiC_8H_{17}), 0.55 (12H, s, $SiCH_3$), 0.28 (12H, s, $SiCH_3$).

Example 22 Synthesis of (R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-hydroxymethyl}naphthyl (7b)

[0073]

[Chemical Formula 41]



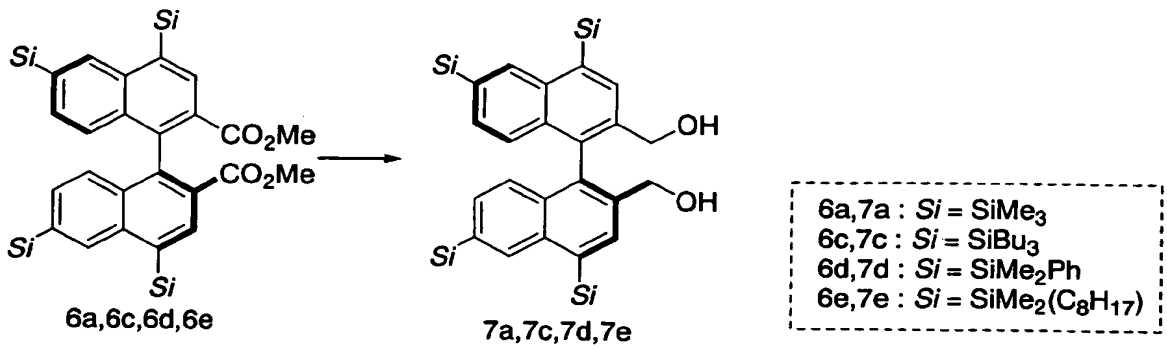
In an argon atmosphere, Compound 6b (0.44 mmol) was added to a tetrahydrofuran solution of $LiAlH_4$ (1.30 mmol) at 0°C, and the mixture was stirred for 1 hour. Subsequently, the reaction mixture was deactivated by sequentially adding MeOH and a saturated aqueous solution of ammonium chloride and the solution was extracted with diethylether. The extract was dried over anhydrous sodium sulfate and was concentrated under reduced pressure. The resulting residue was subjected to a silica gel column chromatography and eluted with a mixed solvent of diethylether/hexane to give Compound 7b in a quantitative yield.

^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.31 (2H, s, Ar-H), 7.84 (2H, s, Ar-H), 7.32 (2H, dd, J = 1.2 Hz, 8.4 Hz, Ar-H), 7.05 (2H, d, J = 8.4 Hz, Ar-H), 4.42 (2H, d, J = 11.6 Hz, $ArCH_2$), 4.16 (2H, d, J = 11.6 Hz, $ArCH_2$), 2.86 (2H, br s, OH), 1.13-0.80 (60H, m, $SiCH_2CH_3$).

Examples 23 through 26 Synthesis of (R)-1,1'-bi-{4,6-bis(trialkylsilyl)-2-hydroxymethyl}naphthyls (7a, 7c, 7d, and 7e)

[0074]

[Chemical Formula 42]



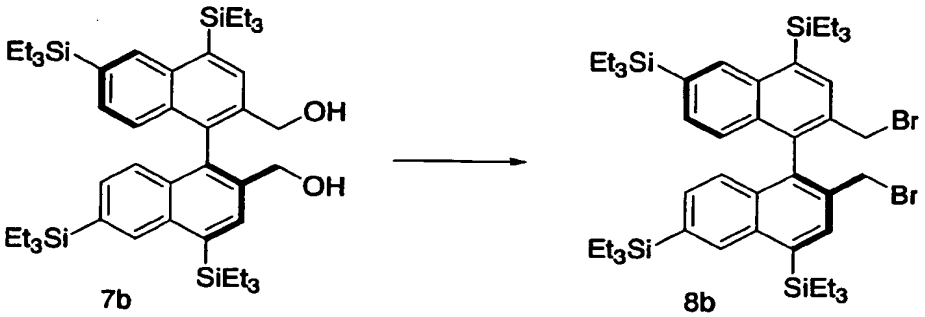
To obtain Compounds 7a, 7c, 7d, and 7e in quantitative yields, the same procedure was followed as in Example 22, except that Compound 6a, 6c, 6d, or 6e was used as the starting material in place of Compound 6b.

[0075]

Example 27 Synthesis of (R)-1,1'-bi-{4,6-bis(triethylsilyl)-2-bromomethyl}naphthyl (8b)

[0076]

[Chemical Formula 43]



Triphenylphosphine (0.315 g, 1.2 mmol) and carbon tetrabromide (0.398 g, 1.2 mmol) were added to a tetrahydrofuran solution (10 mL) of Compound 7b (0.20 mmol),

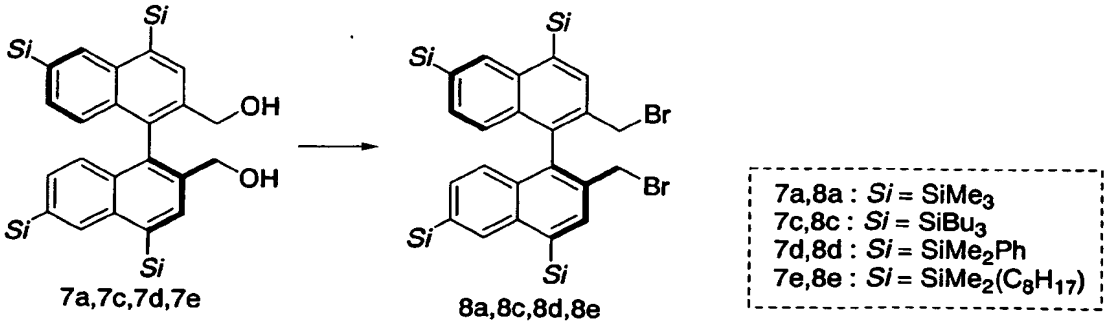
and the mixture was stirred at room temperature for 4 hours. After completion of the reaction, the reaction mixture was poured into water and was extracted with dichloromethane. The dichloromethane solution was dried over anhydrous sodium sulfate and was concentrated under reduced pressure. After concentration, the residue was subjected to a silica gel column chromatography and was eluted with a hexane solvent to give Compound 8b in a quantitative yield.

^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.28 (2H, s, Ar-H), 7.87 (2H, s, Ar-H), 7.34 (2H, dd, J = 1.2 Hz, 8.4 Hz, Ar-H), 7.06 (2H, d, J = 8.4 Hz, Ar-H), 4.24 (4H, s, $ArCH_2$), 1.13-0.80 (60H, m, $SiCH_2CH_3$).

Examples 29 through 32 Synthesis of (R)-1,1'-bi-{4,6-bis(trialkylsilyl)-2-bromomethyl}naphthyls (8a, 8c, 8d, and 8e)

[0077]

[Chemical Formula 44]



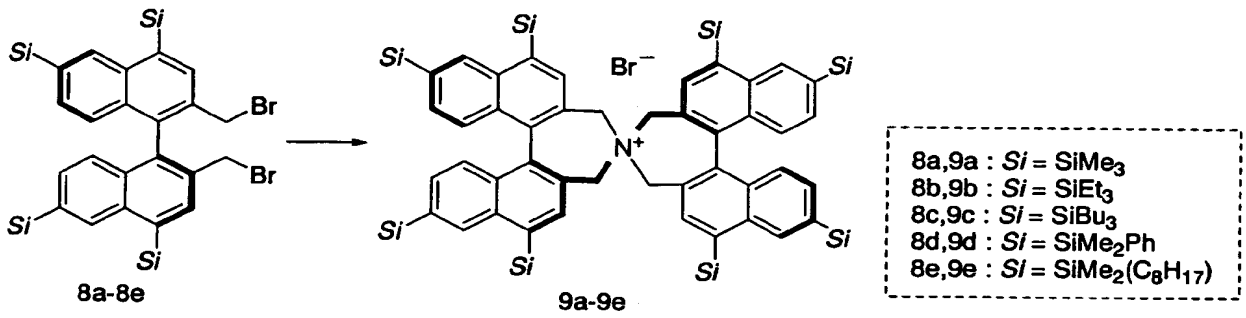
To obtain Compounds 8a, 8c, 8d, and 8e in quantitative yields, the same procedure was followed as in Example 28,

except that Compound 7a, 7c, 7d, or 7e was used as the starting material in place of Compound 7b.

Examples 33 through 37 Synthesis of spiro-bis[{(R)-1,1'-bi-{4,6-bis(trimethylsilyl)naphthyl}}2,2'-dimethyl]ammonium bromides (9a through 9e)

[0079]

[Chemical Formula 45]



A 28% aqueous ammonia (0.77 mL, 12.6 mmol) and acetonitrile (5 mL) were added to one of Compounds 8a through 8e (3.15 mmol). The reaction vessel was sealed and the mixture was stirred for 24 hours while being refluxed. Subsequently, the reaction mixture was poured into water and the solution was extracted with dichloromethane. The extract was dried over anhydrous sodium sulfate and was concentrated under reduced pressure. After concentration, the resulting residue was subjected to a silica gel column chromatography and eluted with a mixed solvent of dichloromethane/methanol to give Compounds 9a through 9e in yields of 25 to 65%.

Chemical data for the products of Examples 33 through 37 are shown below.

<Product of Example 33 (Compound 9a)>

Spiro-bis[{(R)-1,1'-bi-{4,6-bis(trimethylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide: ^{1}H-NMR (400MHz, $CDCl_3$) σ 8.50 (4H, s, Ar-H), 7.80 (4H, s, Ar-H), 7.44 (4H, d, J = 8.8 Hz, Ar-H), 7.30 (4H, d, J = 8.8 Hz, Ar-H), 4.46 (4H, d, J = 14.0 Hz, $ArCH_2$), 4.10 (4H, d, J = 14.0 Hz, $ArCH_2$), 0.73 (36H, s, $SiCH_3$), 0.36 (36H, s, $SiCH_3$).

<Product of Example 34 (Compound 9b)>

Spiro-bis[{(R)-1,1'-bi-{4,6-bis(triethylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.48 (4H, s, Ar-H), 7.91 (4H, s, Ar-H), 7.43 (4H, dd, J = 1.2 Hz, 8.4 Hz, Ar-H), 7.25 (4H, d, J = 8.4 Hz, Ar-H), 4.38 (4H, d, J = 13.2 Hz, $ArCH_2$), 4.08 (4H, d, J = 13.2 Hz, $ArCH_2$), 1.32-0.85 (120H, m, $SiCH_2CH_3$).

<Product of Example 35 (Compound 9c)>

Spiro-bis[{(R)-1,1'-bi-{4,6-bis(tributylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.47 (4H, s, Ar-H), 7.85 (4H, s, Ar-H), 7.36 (4H, d, J = 8.4 Hz, Ar-H), 7.13 (4H, d, J = 8.4 Hz, Ar-H), 4.39 (4H, d, J = 13.6 Hz, $ArCH_2$), 4.15 (4H, d, J = 13.6 Hz, $ArCH_2$), 1.43-0.85 (108H, m, $SiCH_2CH_2CH_2CH_3$).

<Product of Example 36 (Compound 9d)>

Spiro-bis[{(R)-1,1'-bi-{4,6-bis(dimethylphenylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.23 (4H, s, Ar-H), 8.18 (4H,

s, Ar-H), 7.57-7.21 (48H, m, Ar-H), 4.61 (4H, d, J = 13.6 Hz, $ArCH_2$), 4.27 (4H, d, J = 13.6 Hz, $ArCH_2$), 0.81 (12H, s, $SiCH_3$), 0.74 (12H, s, $SiCH_3$), 0.39 (12H, s, $SiCH_3$), 0.38 (12H, s, $SiCH_3$).

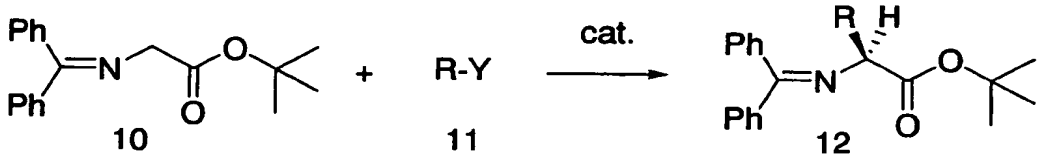
<Product of Example 37 (Compound 9e)>

Spiro-bis[{(R)-1,1'-bi-{4,6-bis(dimethyloctylsilyl)naphthyl}}-2,2'-dimethyl]ammonium bromide: ^{1}H-NMR (400 MHz, $CDCl_3$) σ 8.47 (4H, s, Ar-H), 7.96 (4H, s, Ar-H), 7.41 (4H, d, J = 8.4 Hz, Ar-H), 7.26 (4H, d, J = 8.4 Hz, Ar-H), 4.43 (4H, d, J = 13.2 Hz, $ArCH_2$), 4.11 (4H, d, J = 13.2 Hz, $ArCH_2$), 1.53-0.80 (136H, m, SiC_8H_{17}), 0.73 (12H, s, $SiCH_3$), 0.70 (12H, s, $SiCH_3$), 0.35 (12H, s, $SiCH_3$), 0.34 (12H, s, $SiCH_3$).

Examples 38 through 52 Asymmetric alkylation using Compounds (9a) through (9e) as an optically active phase-transfer catalyst

[0080]

[Chemical Formula 46]



At 0°C, Compound 11 (0.6 mmol) of the general formula (13) shown as R-Y in Table 1 was added to a mixture of Compound 10 of the general formula (12) (0.5 mmol), a phase-transfer catalyst (one of Compound (9a), Compound (9b), Compound (9c), Compound (9d), and Compound (9e)) (0.05 mmol),

toluene (3.3 mL), and a 50% aqueous solution of potassium hydroxide (1.0 mL). The mixture was stirred at the same temperature and was poured into water. The solution was extracted with ether and the extract was washed with saturated brine, followed by drying over sodium sulfate and concentration under reduced pressure. The resulting residue was subjected to a silica gel column chromatography to give an alkylated compound 12 of the general formula (14). The results obtained for different phase-transfer catalysts and different alkylating agents were collectively shown in Table 1.

The optical purity of the reaction products was determined according to the technique described in *J. Am. Chem. Soc.* 1999, Vol. 121, No. 27, 6519-6520.

[0081]

[Table 1]

Run	R−Y	Cat.	Time [h]	Yield [%]	Ee [%]
1	$PhCH_2Br$	9c	172	96	99
2	〃	9d	26	98	98
3	〃	9c	50	92	99
4	〃	9b	6	97	97
5	〃	9a	96	60	92
6	MeI	9c	14	92	93
7	〃	9d	16	92	92
8	〃	9c	10	93	88
9	〃	9b	22	90	89
10	〃	9a	10	92	92
11	$CH_2=CHCH_2Br$	9e	96	98	98
12	$HC\equiv CCH_2Br$	9e	32	96	99
13	EtI	9e	10	87	98
14	HexI	9e	10	81	97
15	*i*Pr−I	9e	15	70	95
16	*c*Pent−I	9e	15	75	96

[TITLE OF DOCUMENT] Abstract

[Object] An optically active α-amino acid derivative, a stereoselectively useful intermediate for the synthesis of pharmaceutical or agrochemical products, which derivative is an optically active quaternary ammonium salt that, when used as an axially chiral spiro phase-transfer catalyst in the asymmetric alkylation of a glycine derivative, gives a high stereoselectivity toward substrates having a small molecule such as methyl iodide, or secondary alkyl halides, and a method for producing the same.

[Solving means] To achieve the objects, ~~(1)~~ an axially chiral spiro-ammonium salt that incorporates an alkyl- or aryl-substituted silyl group as a substituent on the aromatic ring is used as a phase-transfer catalyst in the asymmetric alkylation of a glycine derivative.